Modeling Shelf Stratigraphy

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Objectives

- Characterization of sea floor and shelf stratigraphy
- Method: geological reconstruction and 2D SedFlux numerical modeling

- Example of New Jersey shelf stratigraphy

- Determine sea floor variability
- Method: 2D SedFlux sensitivity tests

Numerical models: Hydrotrend and SedFlux

HydroTrend

INPUT(t)

T, P, A, H, ELA +
statistical properties

PROCESSES

Hydrological mass balance (daily)
$Qi = Qsurf + Qniv + Qgw + Qice$
Empirical relation $Qs \sim A, H, T$
$Qs \sim \psi\ (Qi / Qmean)^c$

OUTPUT (t)

- Q, Qs, Qb (daily)
for 5 grain-size classes

2DSedFlux

INPUT(t)

sea level(t), bathymetry (t-0)
Q, Qs, Qb

PROCESSES

River: avulsion, floodplain SR
Marine: delta plume, stormreworking
Basin: compaction

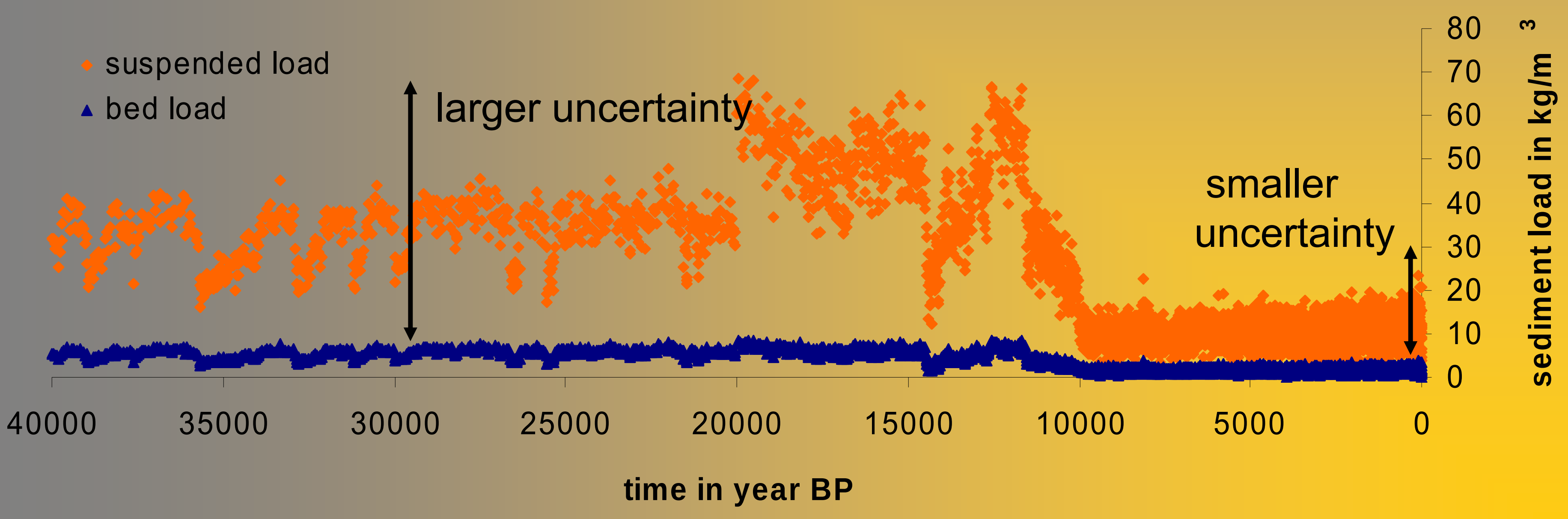
OUTPUT (x,z,t)

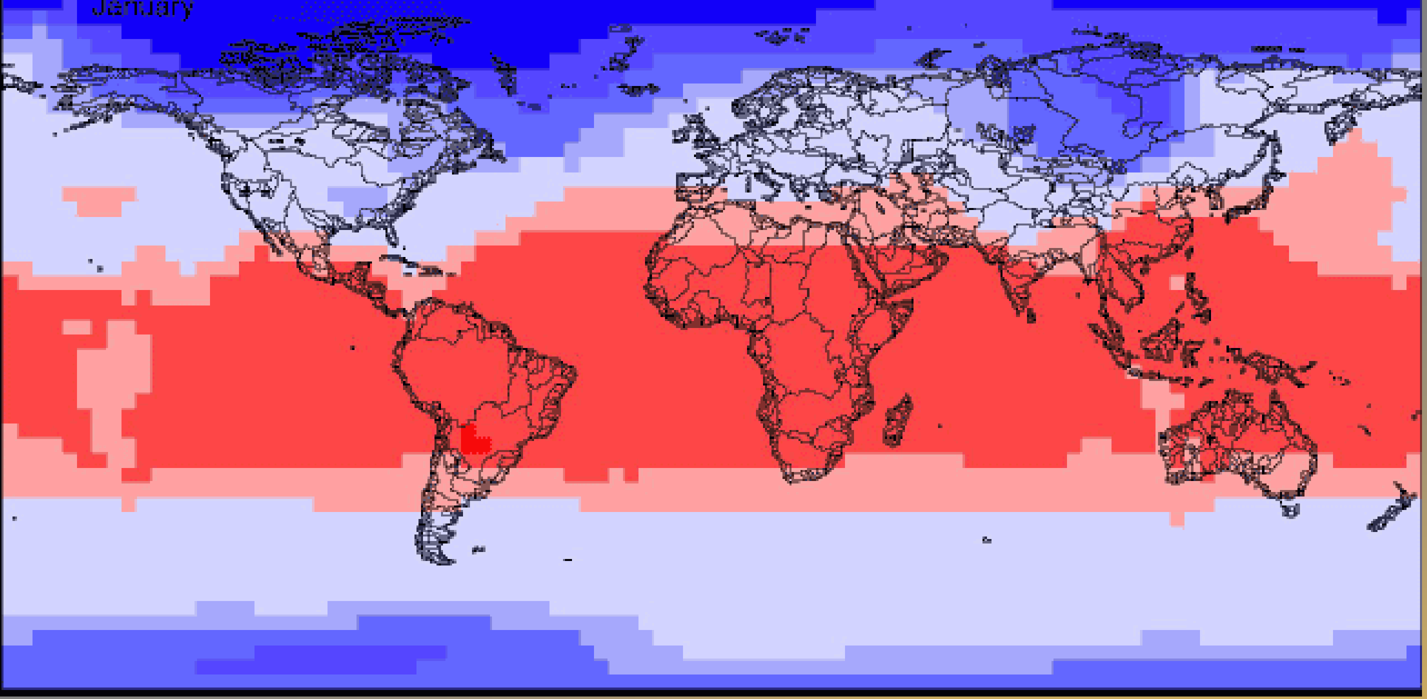
- 2D-geometry
- grain size, permeability, bulk density, porosity

Boundary Conditions: River Sediment

Climate-driven model HydroTrend predicts sediment load over time as function of:

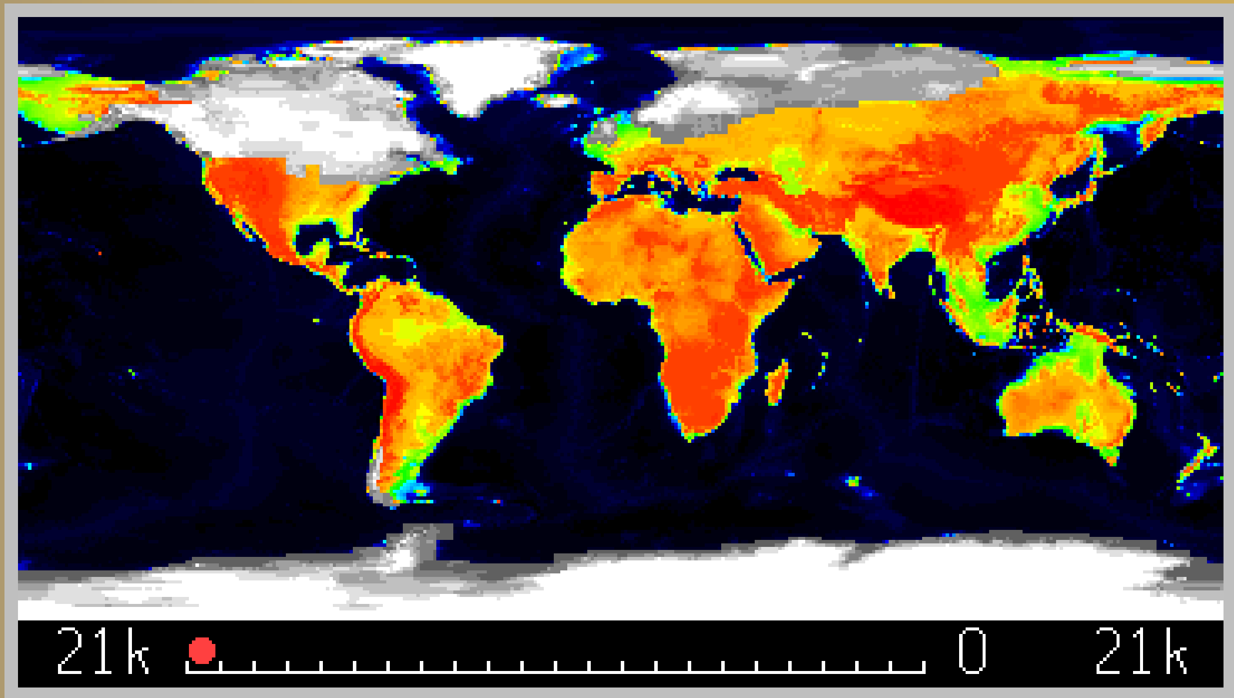
- **A(t), H(t), drainage basin geometry retrieved from Digital Elevation Models**
- **P(t), T(t), precipitation & temperature retrieved from climate stations and Community Climate Model paleo-realizations (CCM1), interpolated with climate proxies**
- **Qice(t), ice melt retrieved from glaciological models**
- **TE(t), sediment trapping efficiency based on lake areas in basin**





CCM1

Global temperature at 21 kBP

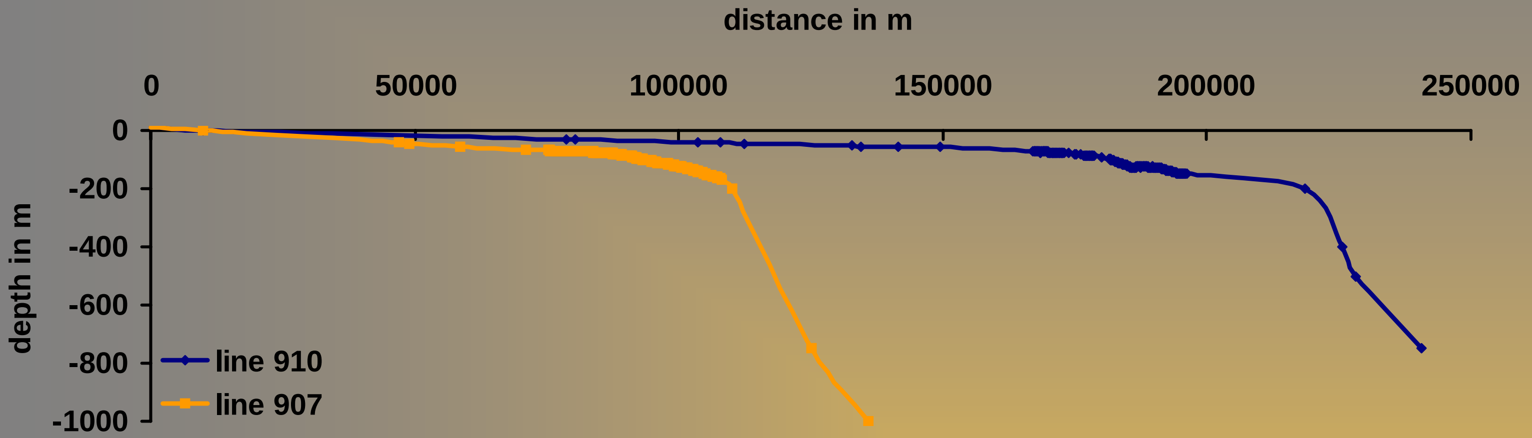


ICE4G Global Ice Cap melt

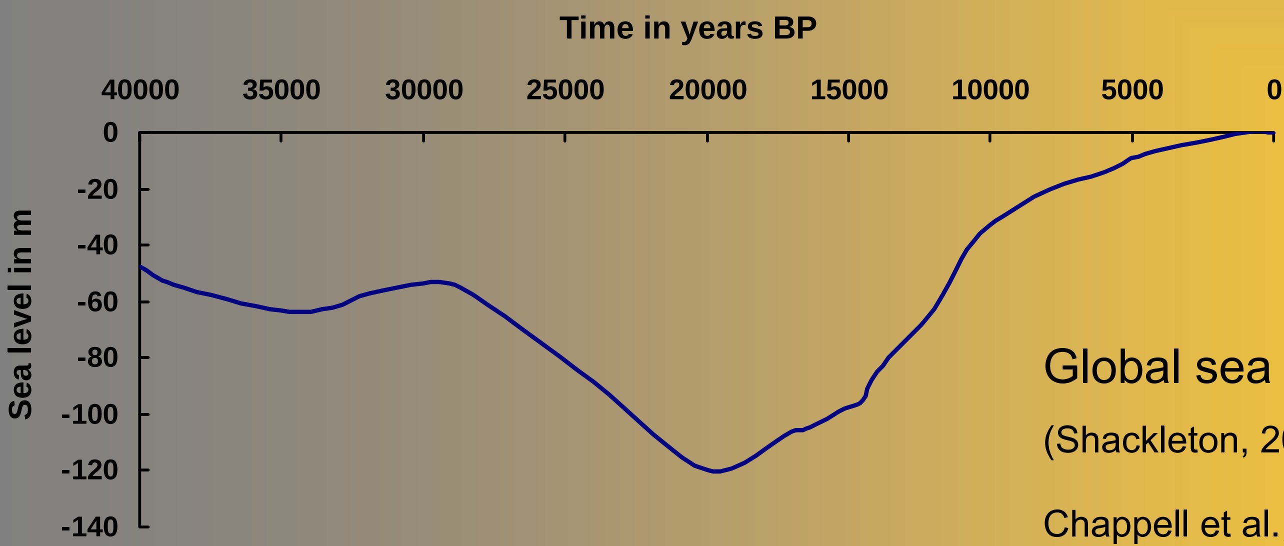
21kBP to present-day

(Peltier et al., 1994).

Boundary Conditions:
Initial profile and Sea Level history



R-reflector based on seismic data interpretations by Goff & Gulick, UTA



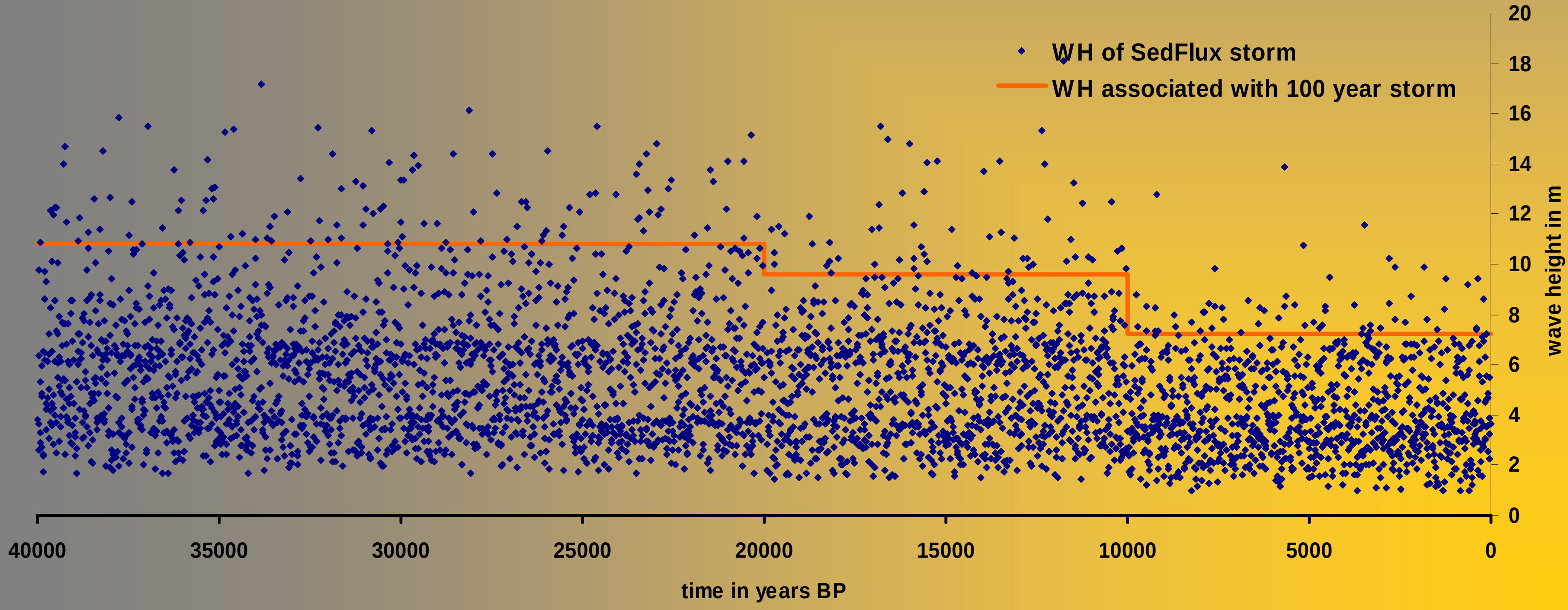
Global sea level curve

(Shackleton, 2000; Bard et al., 1990;

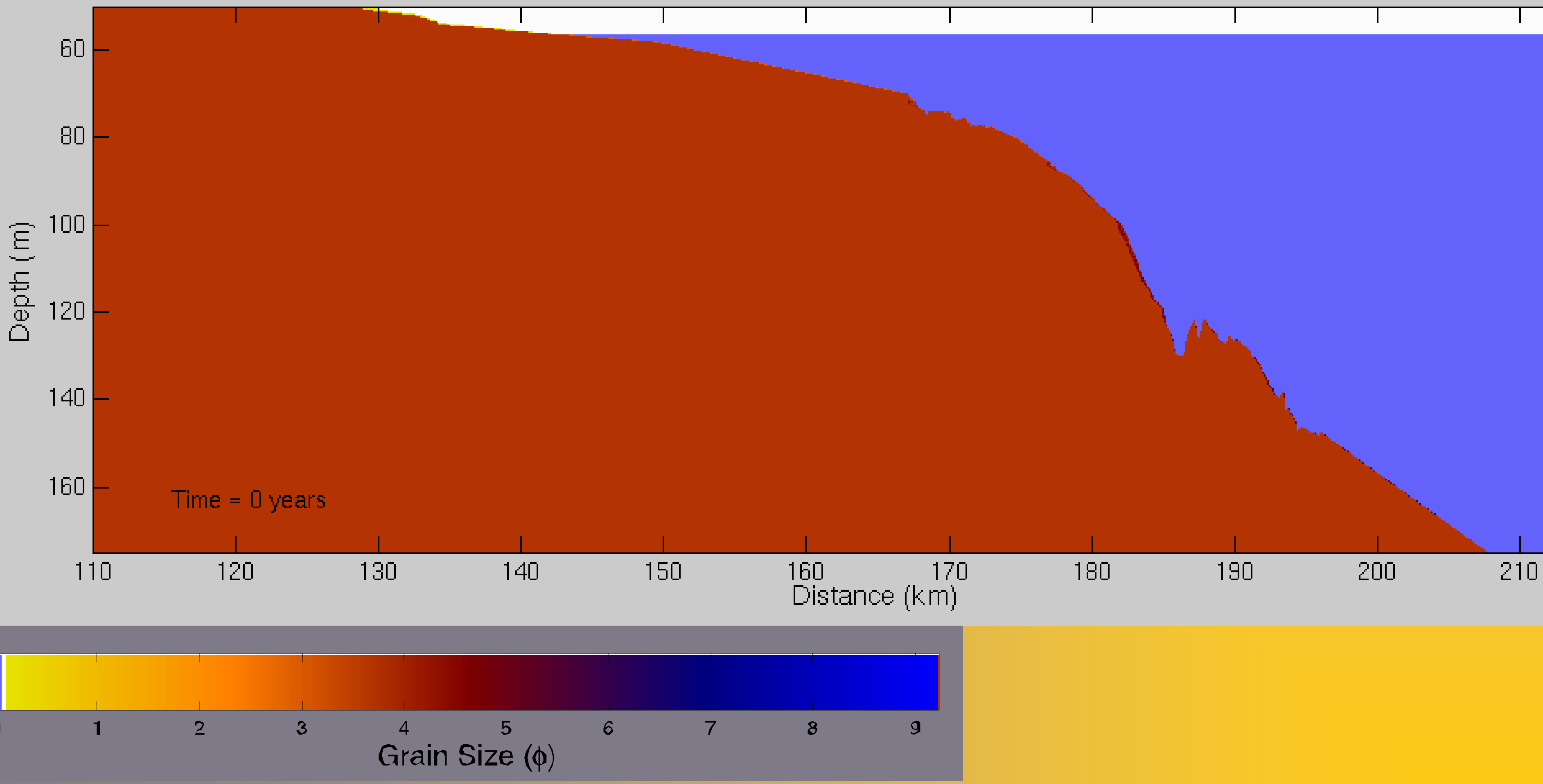
Chappell et al., 1996)

Boundary Conditions: Storm Climate

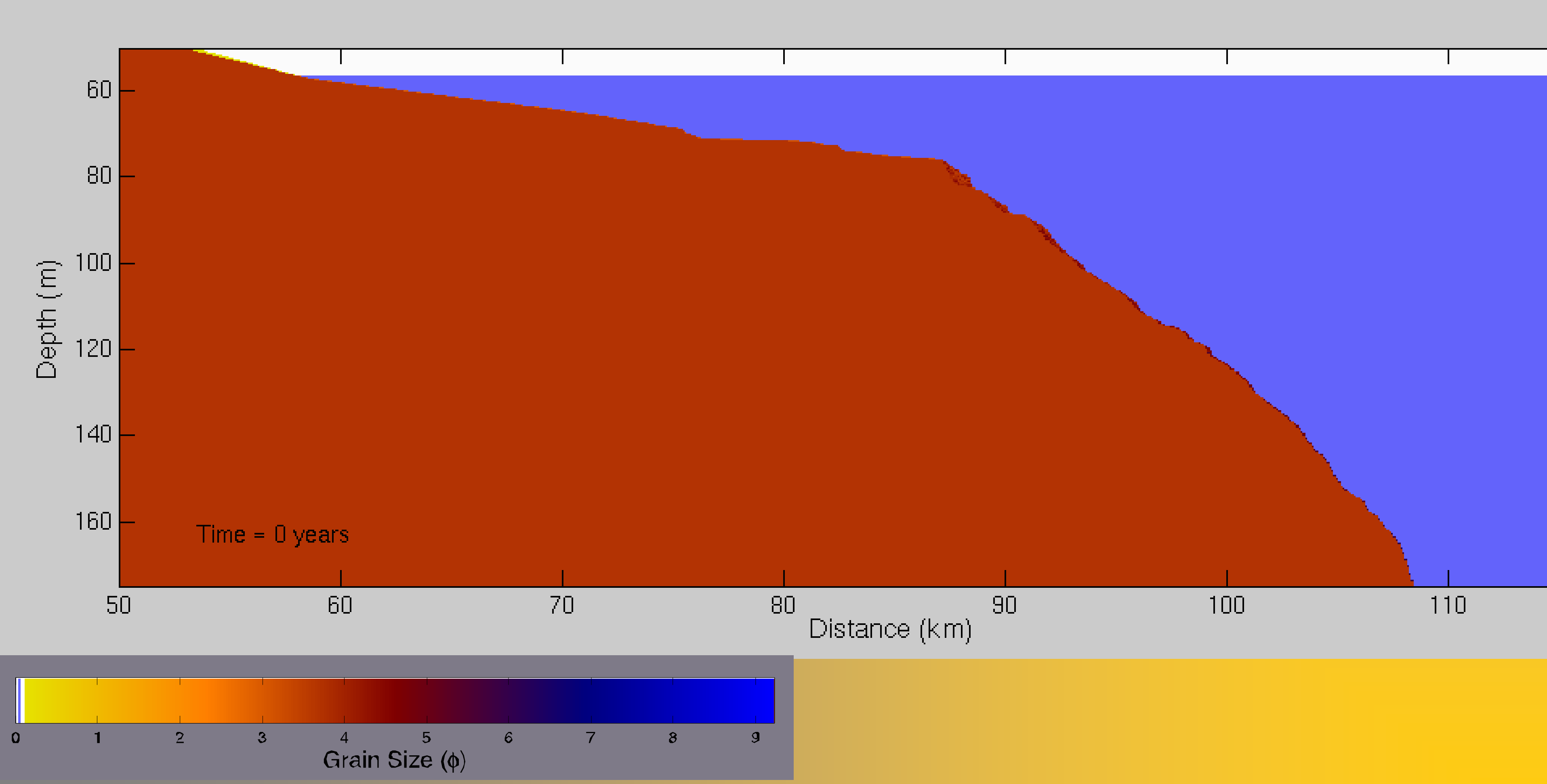
- WAVE-WATCH III provides global wave climate, (3hr time intervals)
- Use the significant wave height (H)
- to set SedFlux log-normal wave height distribution use the peak month
- SedFlux Wave Height = (mean sign. H + 2 σ)
- offshore NJ this would be 7.2 m



SedFlux simulation of 40,000 years of shelf deposition: line 910

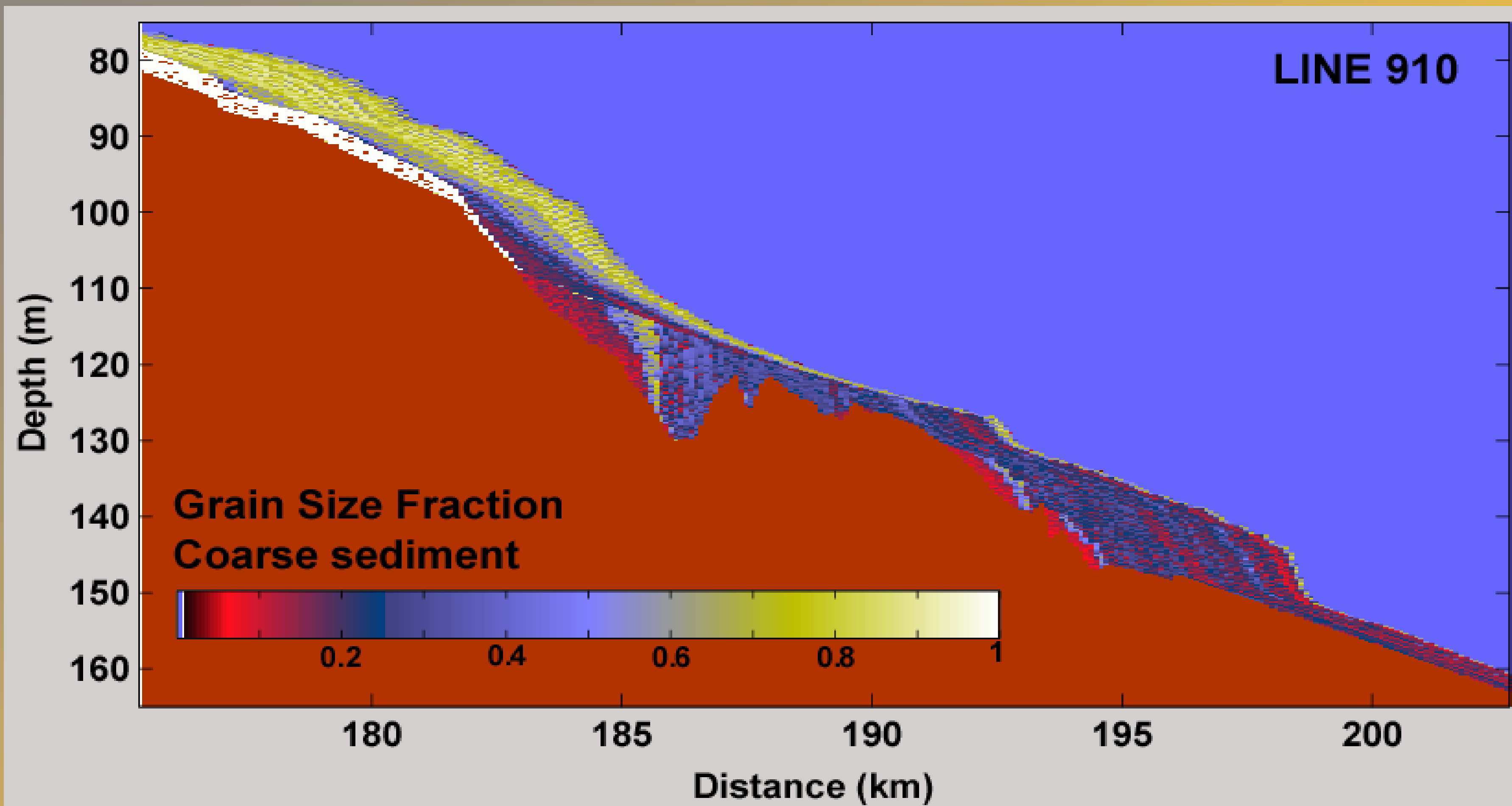


SedFlux simulation of 40,000 years of shelf deposition: line 907



SedFlux predicted properties

- grain size, bulk density, porosity, permeability per 10 cm bin
- NEW → volume fraction per grainsize



Testing SedFlux against observed data

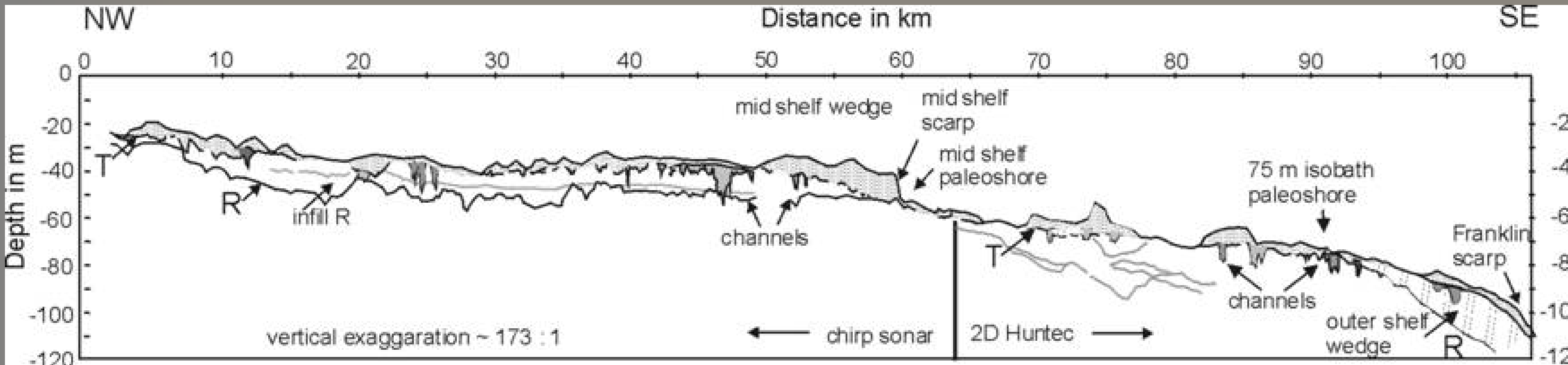
FIRST-ORDER TEST

- High resolution seismic data interpretation: mapped the thickness of sediment above the R-reflector
- 98 seafloor grab samples (grain size, % coarse, % fine)
- dbSEABED (Jenkins, INSTAAR), usSEABED (Williams, USGS)

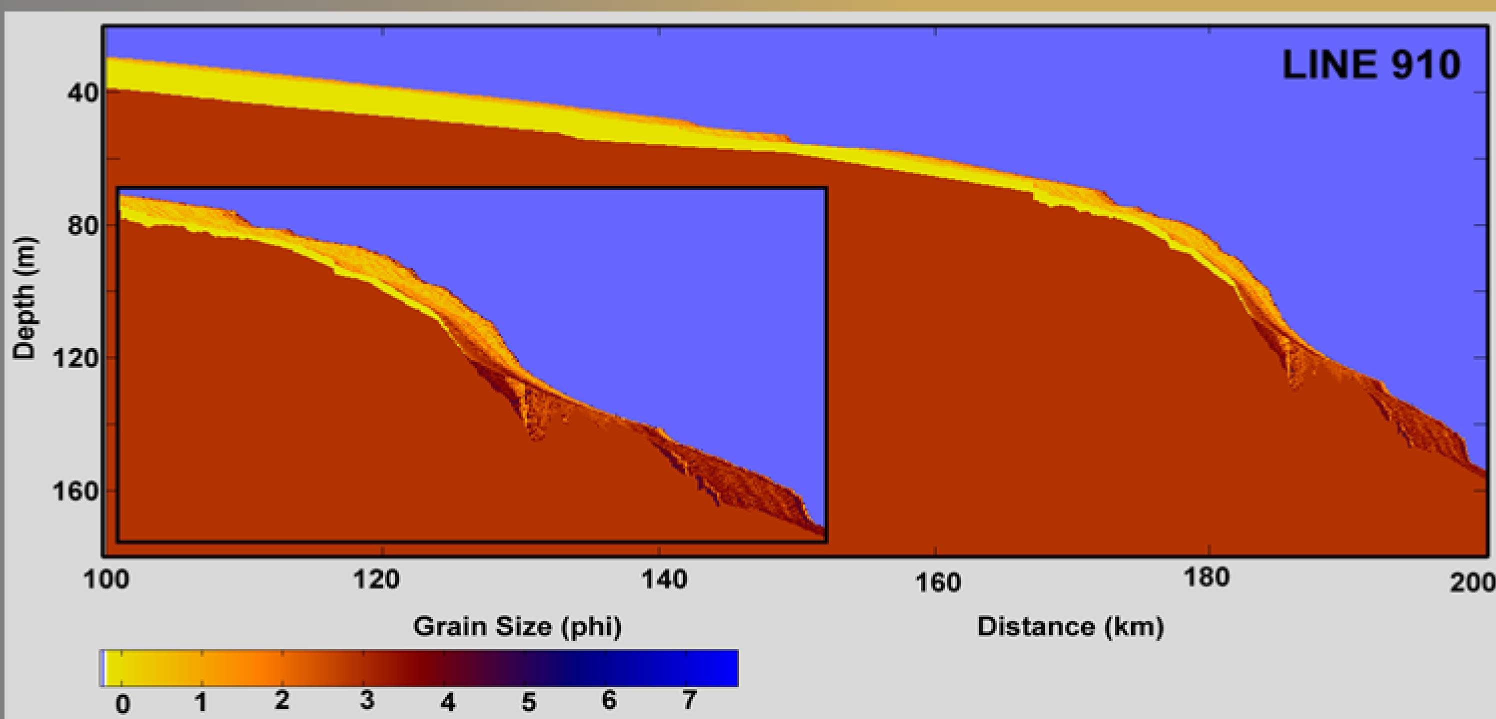
BLIND TEST (Pratson, Duke; Kraft, UNH; Holland, Penn State)

- Acoustic scatter measurements
- Low grazing angle seismic experiments (7 stations)

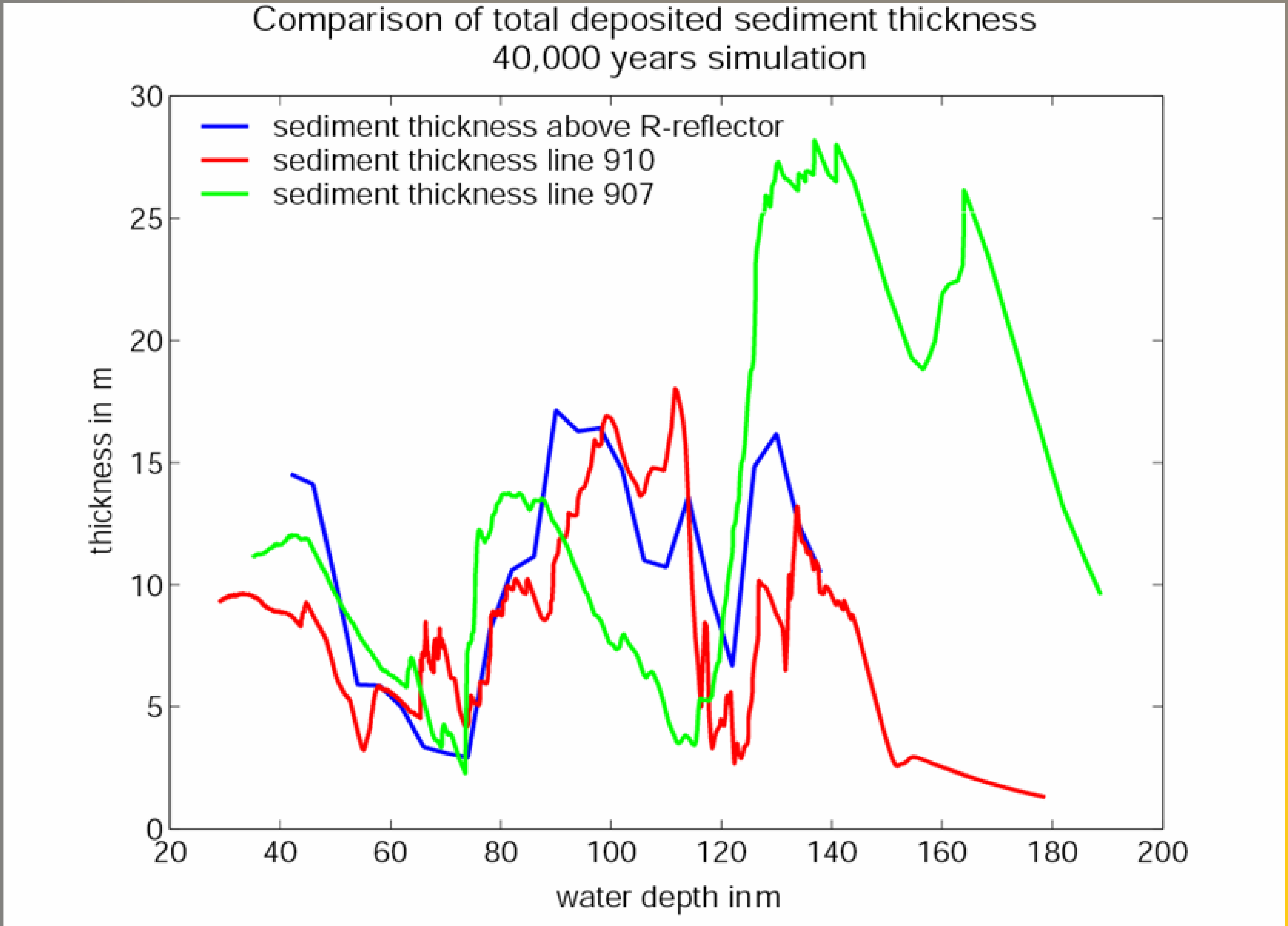
Shallow Stratigraphy: predicted vs. observed



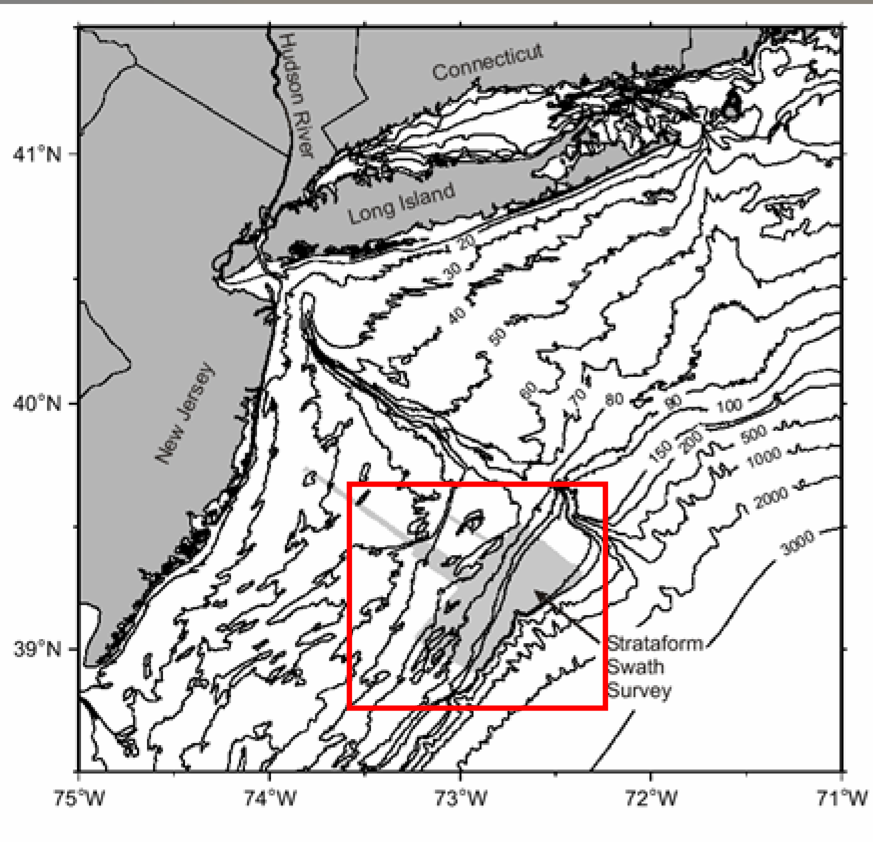
Seismic reconstruction of Chirp sonar & 2D Huntec data, *after Duncan et al, 2000; Goff, UTA*



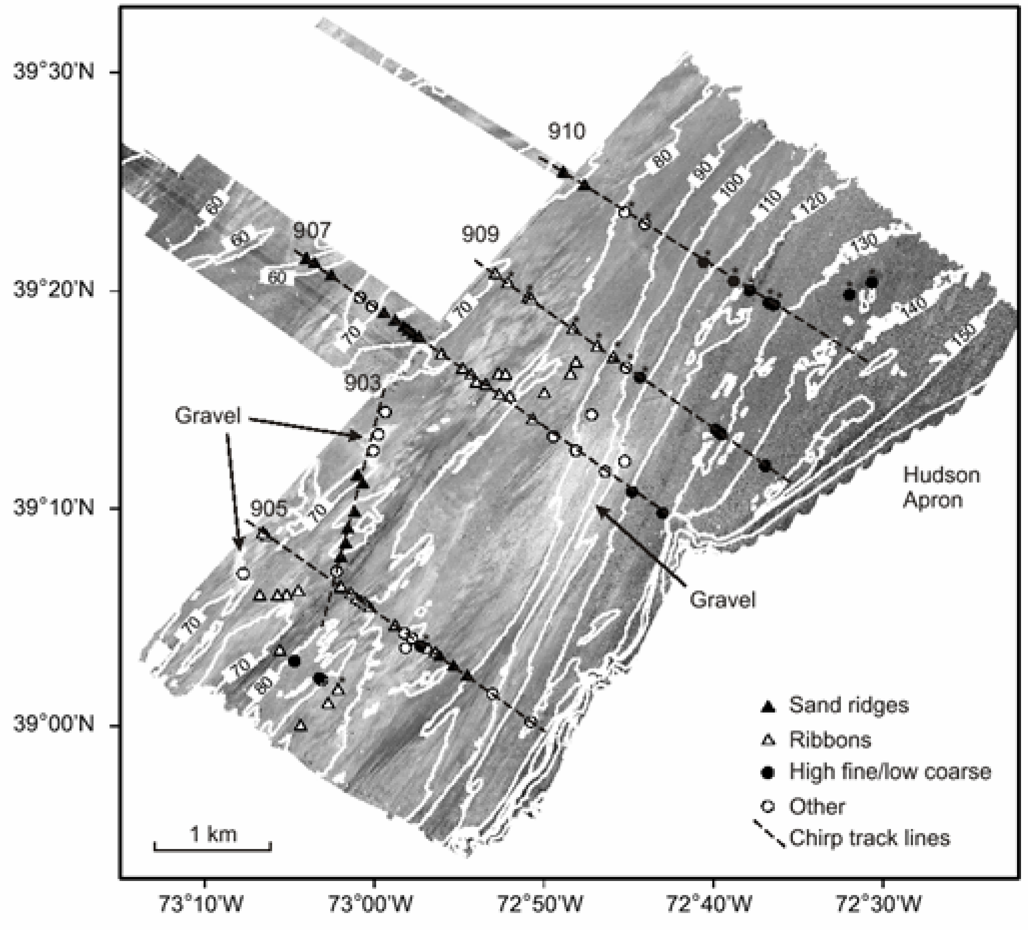
Large-scale layer geometry; predicted vs. observed



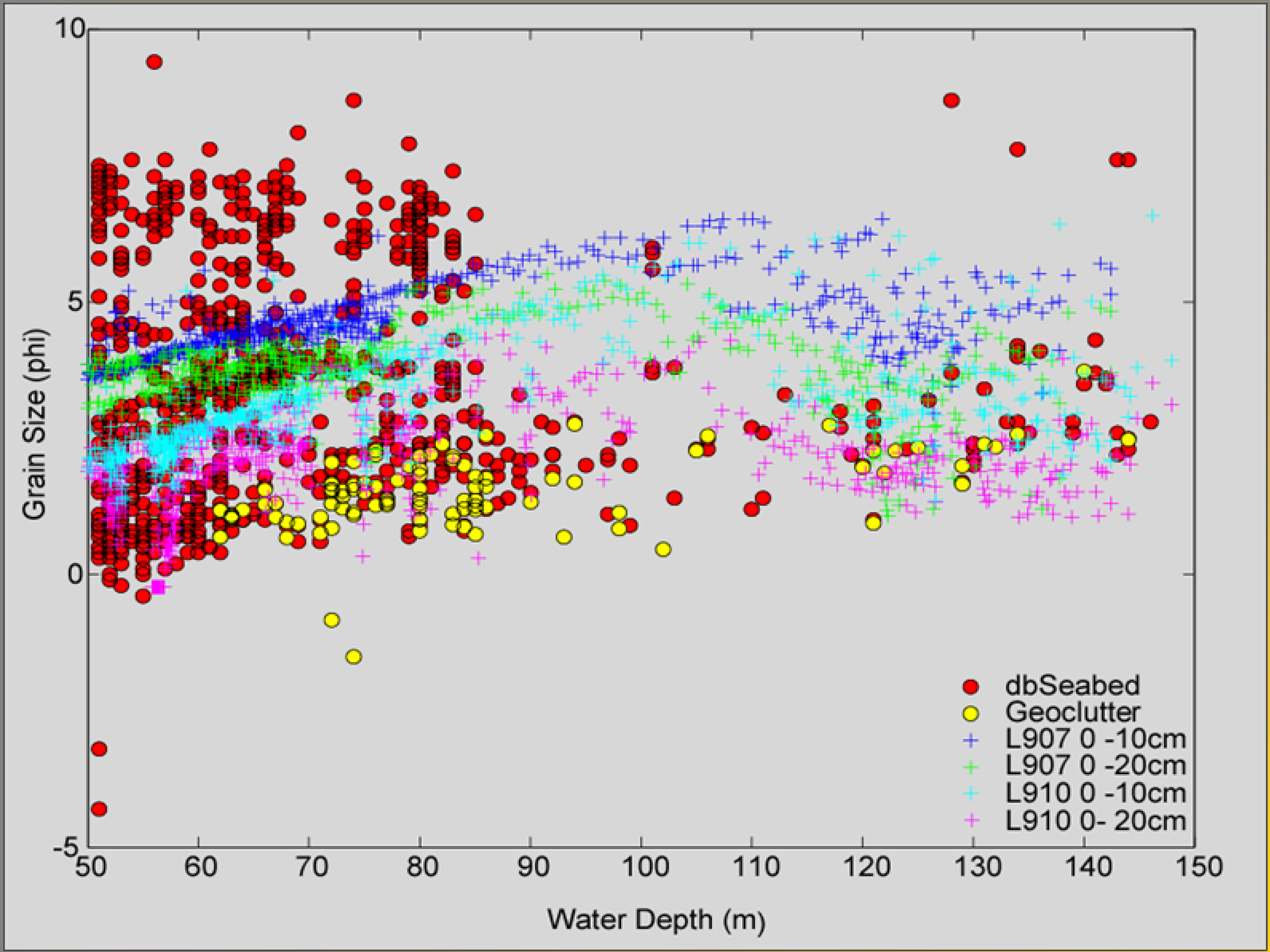
Grab Sample Locations



- 98 grab samples, (Goff et al., 2003)
- taken in the 2001 with Smith-McIntyre grab sampler (sampling size 500-1000g)

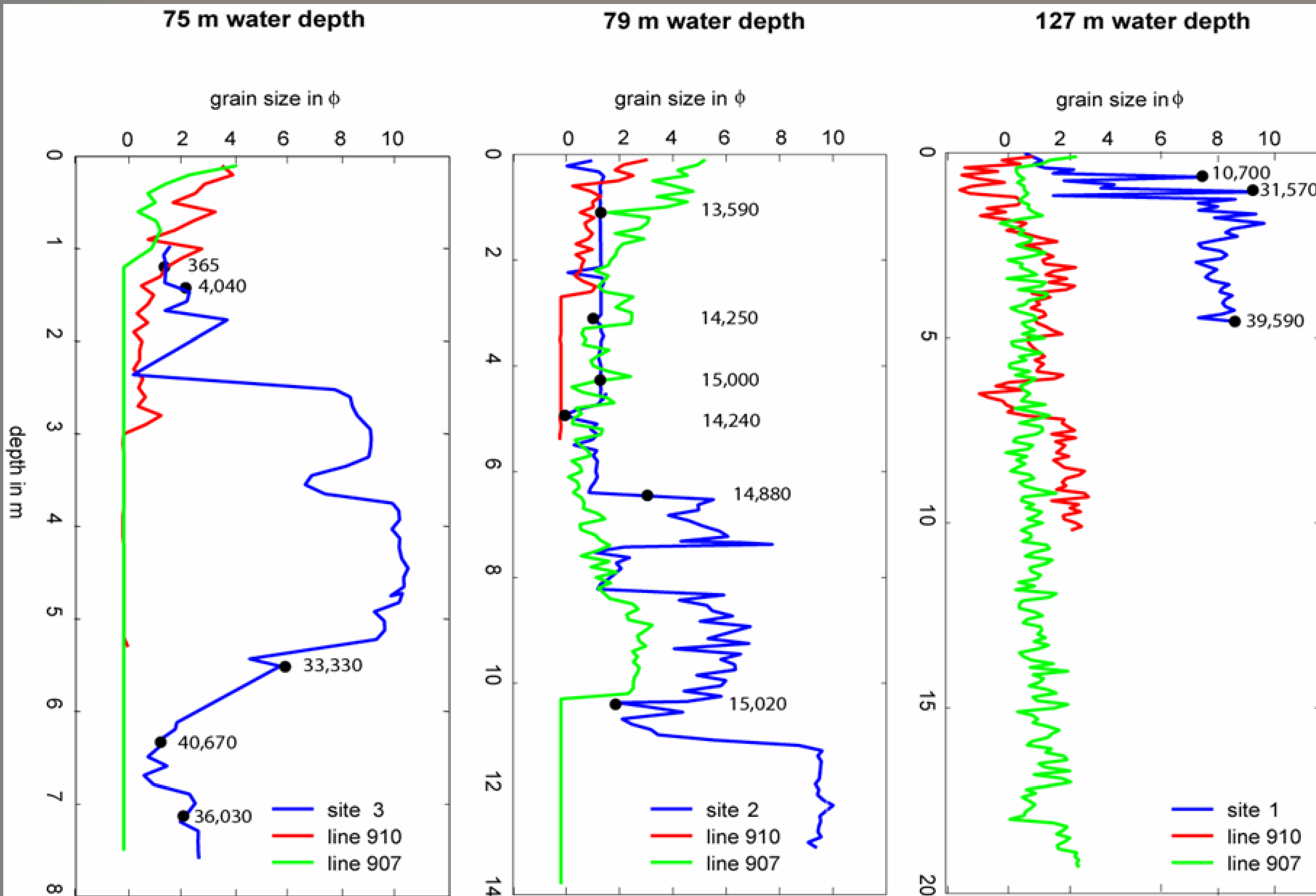


Seafloor grain size: predicted vs. observed



3 shallow cores in incised channels

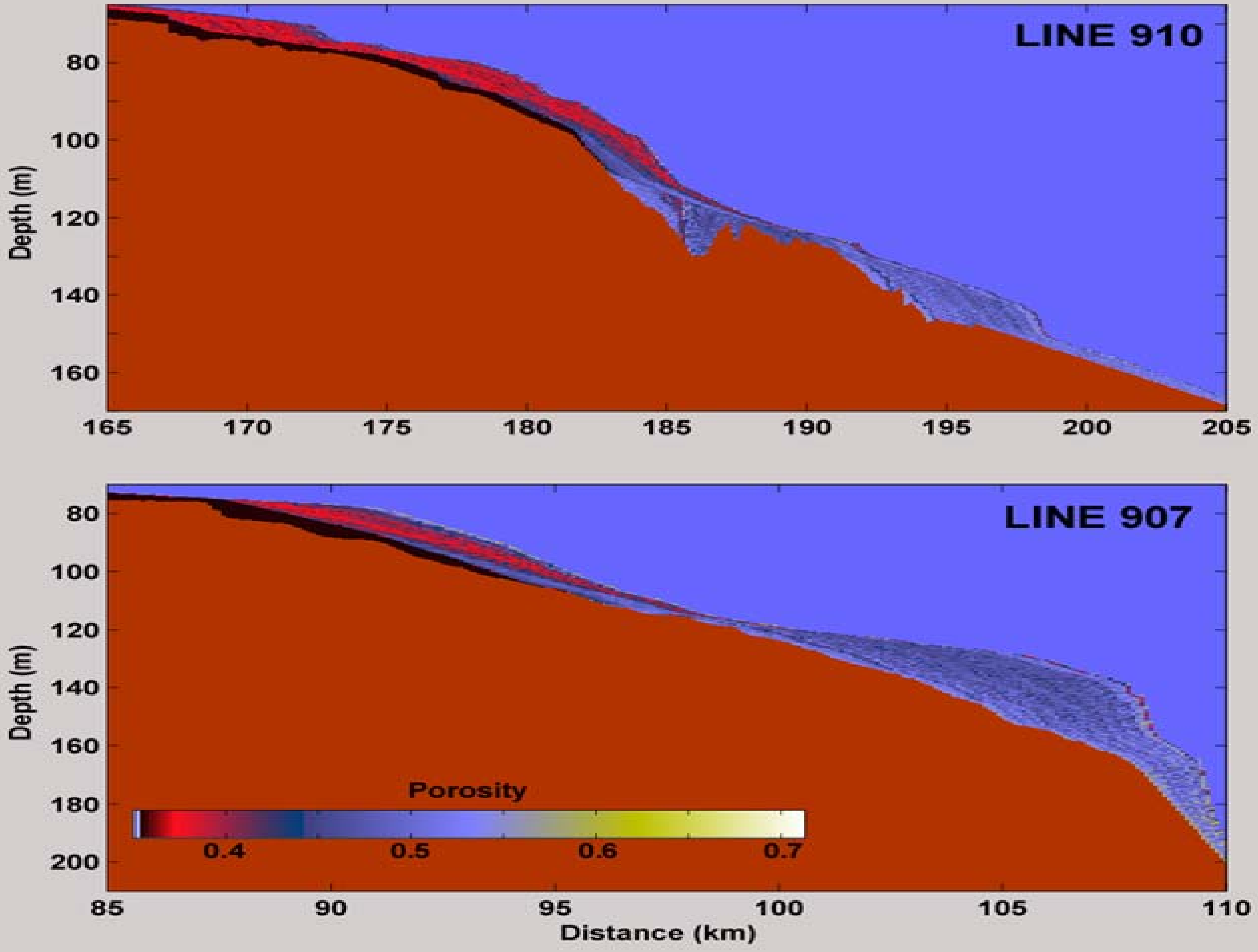
(Alexander et al. 2003)

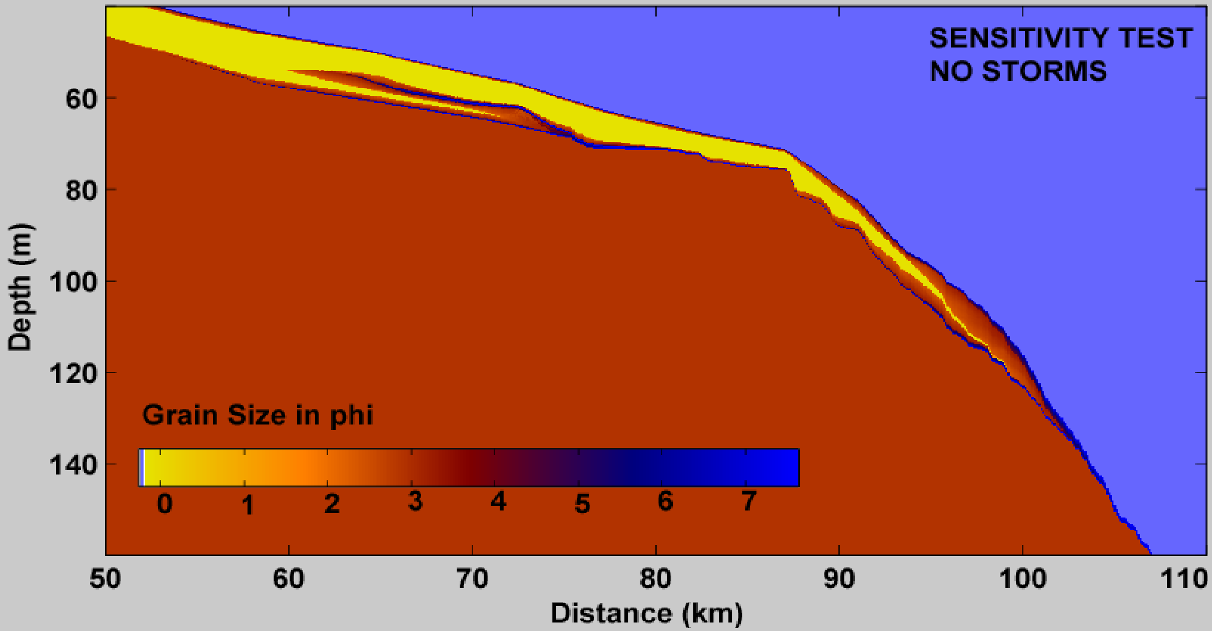


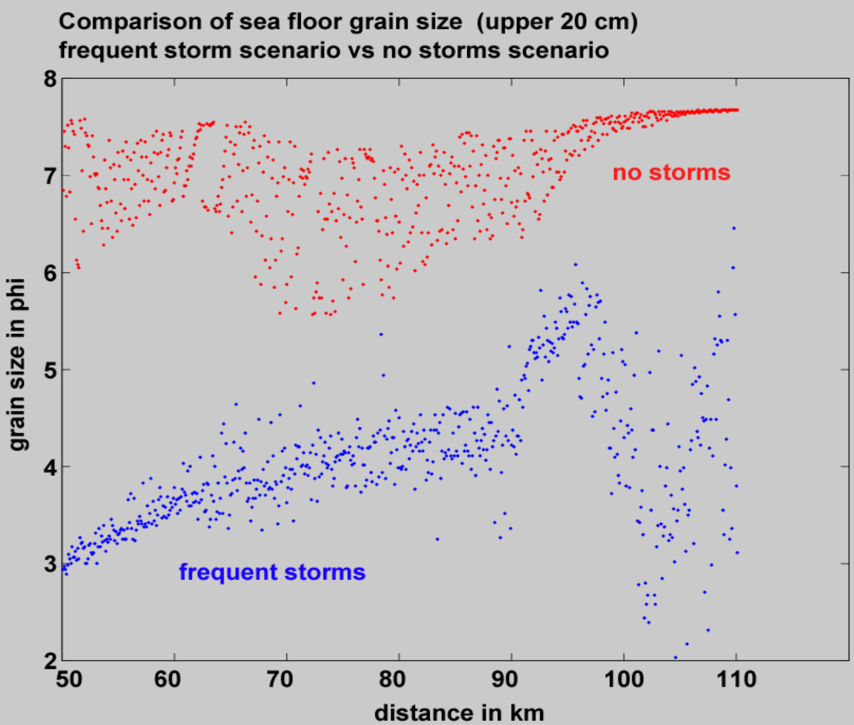
Examples of Sensitivity tests

Early phase in the DRI project: unconstrained New Jersey realization and 20 sensitivity test with large ranges in primitive geological parameters.

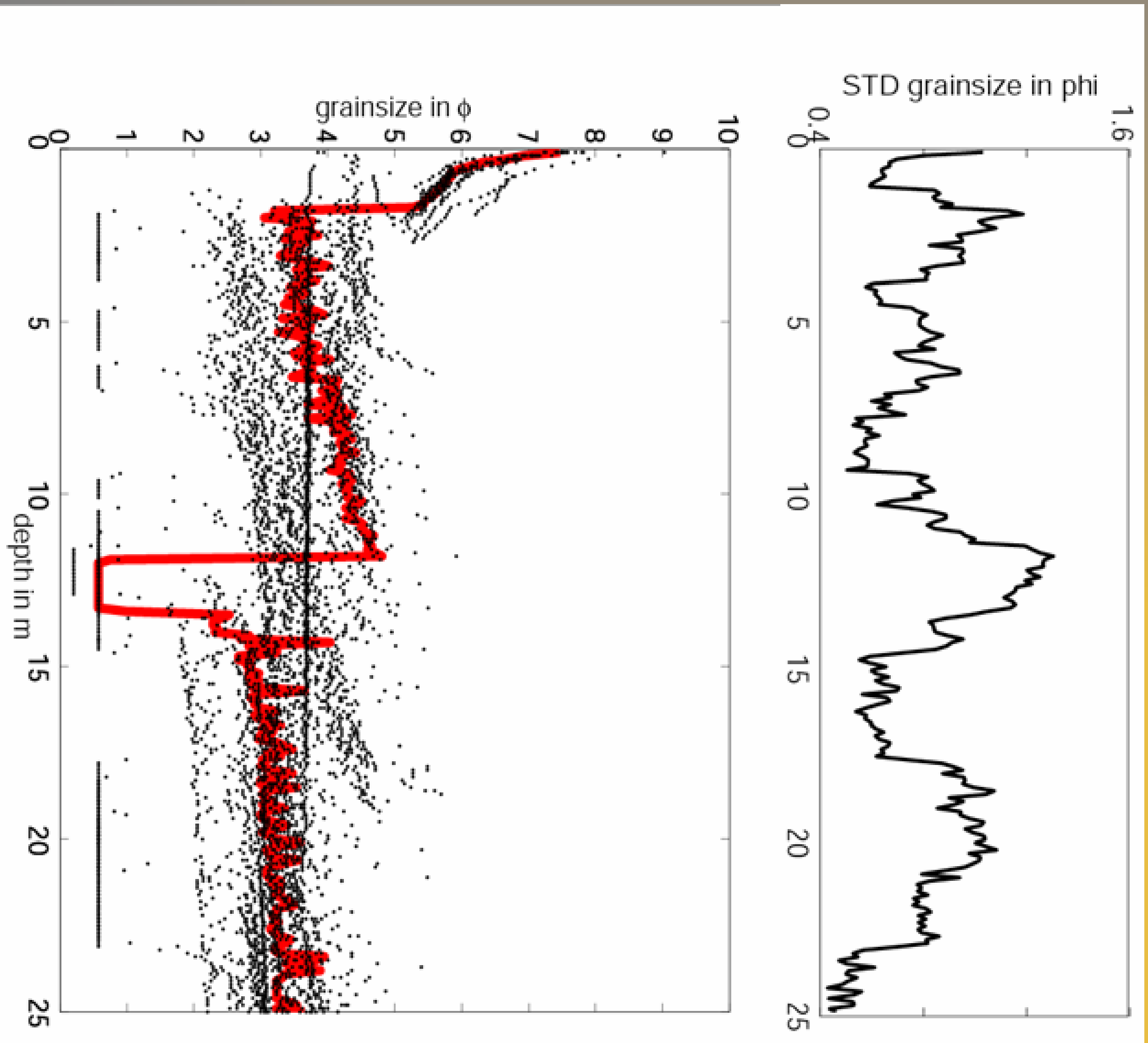
Uncertainty in Boundary Conditions	Uncertainty in SedFlux Processes
Initial profile input (line 907, line 910)	Effect of 2D-3D issues definition of basin width (BW)
Initial grain size input (Hamilton paper vs. ODP)	Storm Reworking Module Scaling of duration and frequency of storms


LINE 910
Depth (m)
80
100
120
140
160
165
170
175
180
185
190
195
200
205
LINE 907
Depth (m)
80
100
120
140
160
180
200
Porosity
0.4
0.5
0.6
0.7
85
90
95
100
105
110
Distance (km)

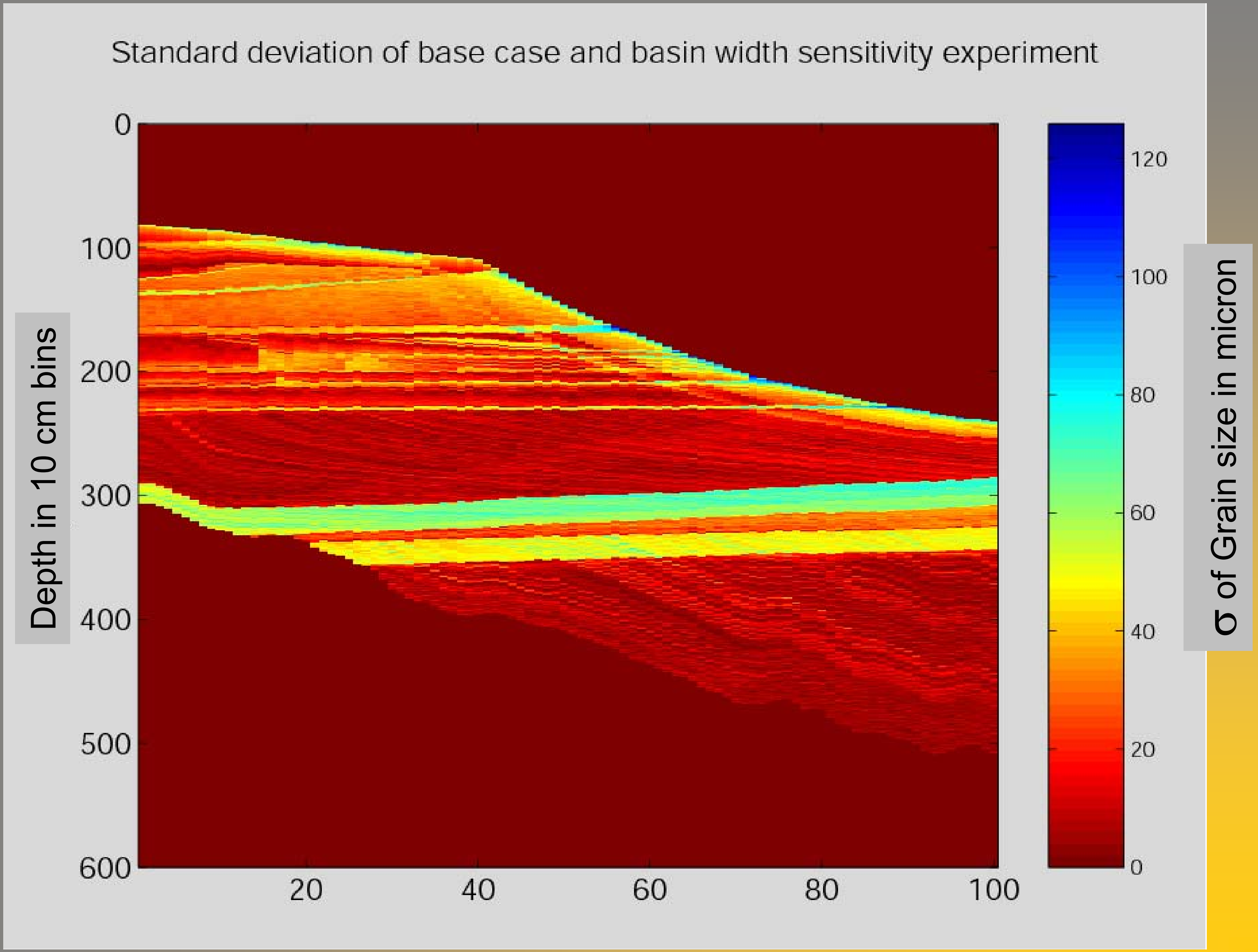

SENSITIVITY TEST
NO STORMS
Grain Size in phi
0 1 2 3 4 5 6 7
Depth (m)
60
80
100
120
140
50 60 70 80 90 100 110
Distance (km)


Comparison of sea floor grain size (upper 20 cm)
frequent storm scenario vs no storms scenario
no storms
frequent storms
grain size in phi
2 3 4 5 6 7 8
50 60 70 80 90 100 110
distance in km

Sensitivity tests: map out the variability in prediction



For any pseudo-well the grain size with depth is determined, and attached to this prediction the range of the grain size prediction over the sensitivity tests


Standard deviation of base case and basin width sensitivity experiment
Depth in 10 cm bins
0
100
200
300
400
500
600
20
40
60
80
100
σ of Grain size in micron
120
100
80
60
40
20
0

Conclusions

- SedFlux is able to predict long-term stratigraphic patterns in shallow margin (geometry at 100m longitudinal resolution and physical properties at 10 cm depth resolution).

- High-resolution input data are increasingly online available on global scale (e.g. present-day climate, paleo from CCM), which makes SedFlux seafloor predictions possible in data-sparse areas. The uncertainty in these boundary conditions can be significant, but this does not necessarily propagate into the seafloor prediction.

- SedFlux provides a method to quantify variability due to uncertainties in the boundary conditions by running different input scenarios = sensitivity tests. A high-resolution output matrix can be associated with different resolution layer models of standard deviations in predicted data

Case study Malta Plateau